

Summary of the dissertation with the title

“Modelling and analysis of battery energy storage integrated wind power system with multi-source converter using software PSCAD”

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The initial point of this thesis is the recognition of the inherent challenges posed by the integration of wind power into the electrical grid, particularly due to the intermittent and variable nature of wind energy. These fluctuations can lead to significant instability in power supply, which poses a risk to grid reliability and performance. To address this issue, the thesis begins by exploring the potential of integrating a Battery Energy Storage System (BESS) with wind power systems, with a specific focus on developing a control strategy for the DC-link. This integration is proposed as a solution to enhance power management and maintain grid stability, forming the foundational premise of the research.

Wind energy, a prominent renewable resource, has seen rapid expansion, but this growth introduces complexities in maintaining power system stability due to the variable nature of wind. This unpredictability necessitates energy storage solutions to balance supply and demand effectively. Traditional wind power systems, lacking storage capabilities, have required grid expansions and modernizations to manage power fluctuations. A promising approach, suggested in this thesis, involves integrating a multisource converter-based wind energy system with battery energy storage, making wind turbines more dispatchable by ensuring constant power through quick charging and discharging responses.

Wind Energy Conversion Systems (WECS) have proven more cost-effective than fossil fuels, making research into wind power increasingly crucial. In this context, a unique model has been developed, integrating a battery energy storage system at the DC-link of a Type-4 wind turbine. The control system manages power output to the grid based on grid demand and wind power availability, while maintaining stable DC-link voltage. Simulation results, conducted using PSCAD/EMTDC software, demonstrated effective control of the system under various wind conditions and grid requirements. The simulation results illustrate the control of a DC-link integrated battery energy storage system at different set point wind speeds and set point grid power as well as with time series wind data. In the end State Of Charge(SOC) permit control approach has also been illustrated.

This intelligent backup system is crucial for maintaining power system stability. The study proposes using energy storage to support system strength, enabling high penetration of renewables in weak networks. Simulations modeled in PSCAD analyze the dynamic behavior of wind power systems under disturbances, focusing on ride-through capabilities during dynamic events. The research compares two approaches for fault ride-through in

grid-connected Type-4 wind turbines with fully rated converter, both utilizing battery storage for enhanced LVRT capabilities in strong and weak grid conditions. The study underscores the importance of optimizing BESS to stabilize system operations, maintain power quality, and ensure grid stability during faults, with comprehensive simulations conducted in PSCAD software to validate the findings.

The findings of this research can be summarized in some of the main achievements.

Firstly, this topology represents a forward-thinking approach to modern power grids, emphasizing sustainability, efficiency, and cost-effectiveness. By balancing renewable energy generation with advanced storage and demand management, it can provide smooth power during on-peak demand and can save excess power from the wind side during off-peak demand, and provide economic advantages regarding unit prices of power delivery it can deliver reliable and economical electricity. The strategy improves the overall stability of the grid by maintaining a consistent power supply, even during periods of high wind variability.

Secondly, the design of the battery system will be such that it can be easily installed on a rack inside the tower. This control system represents a sophisticated approach to modern energy management, particularly in grids with high penetration of renewable energy sources. By focusing on DC-link voltage stability and the efficient use of BESS, it helps create a more reliable electrical power system. The proposed DC-link control strategy successfully integrates the BESS for providing peak shaving with the wind power system, effectively smoothing out power fluctuations. The research demonstrates that the integration of BESS with DC link control can significantly enhance the efficiency of power management in wind energy systems.

Finally, the ride-through behavior under different disturbance scenarios has been analyzed and implemented by including additional control topologies. The investigation was carried out to enhance the existing voltage ride-through capability of the permanent magnet synchronous generator (PMSG) wind turbine by adding a BESS control system.

The dissertation employs implementation of control methods to develop and validate the proposed DC-link control strategy. The research involves modeling the integrated wind-BESS system, designing the control algorithm, and testing its performance under various conditions to ensure effective power management and grid stability.

This concludes that the integration of a BESS into a wind power system, combined with effective DC-link control, offers a robust solution for managing power and ensuring grid stability. The findings contribute valuable insights into renewable energy integration, particularly in optimizing the performance of wind power systems.

The research suggests further exploration of advanced control techniques and the integration of other renewable energy sources. Future studies could also investigate the scalability of the proposed system for larger grid applications. This work is significant for advancing the field of renewable energy, providing a practical solution for one of the key challenges in wind power integration ensuring consistent and reliable power delivery to the grid. It supports the broader transition to sustainable energy by enhancing the stability and reliability of renewable power systems.